

# The LEGS TPC

## Design Requirements

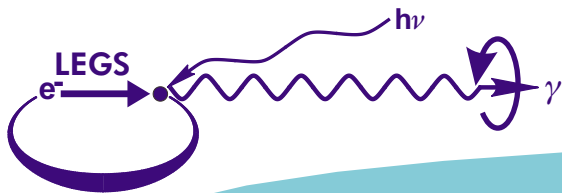
Craig Thorn

Review of LEGS Experiment

BNL

Upton, NY

May 12, 2005



## LEGS TPC Design

**An essential element of SASY providing**

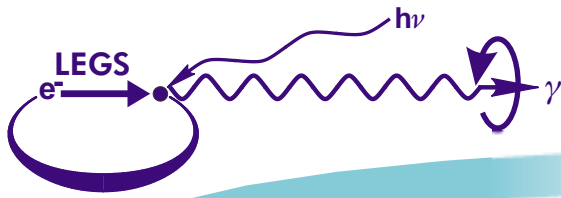
- $\pi^\pm$  charge separation
- increased angular coverage
- improved resolution

**Design is eased by**

- low event multiplicities ( $\leq 3$ )
- low event rates ( $\leq 2$  kHz)

**Design is complicated by**

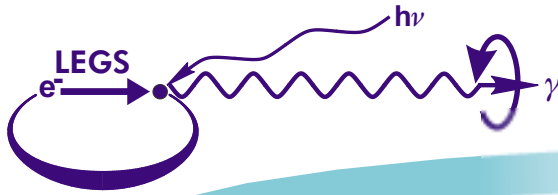
- small size to fit in XTAL Box (pad density is 10x that of Star TPC)
- low mass to allow  $\gamma$  detection (0.4 RL)



# The LEGS TPC

## Design Specifications

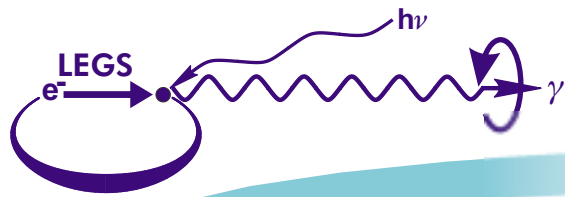
Available Volume	51.5 x 51.5 x 81.7 cm
Inner active diameter	8.7 cm
Outer activediameter	35.7 cm
Active length	50 cm
Max. Electric field (voltage)	700 V/cm (35kV)
Magnetic field	1.8 T
Track distortion from $\Delta b_r$	<1 mm
Drift time	<5 $\mu$ s
Filling gas	Ar + CF <sub>4</sub> + C <sub>2</sub> H <sub>6</sub> @ STP
Gas multiplication	low ( $\leq 1000$ )
Number of track points	>20 pad rows
$r\Delta\phi$ resolution	<200 $\mu$ m
$\Delta z$ resolution	<20 ns
Readout channels	~8000



# The LEGS TPC

## Predicted Performance

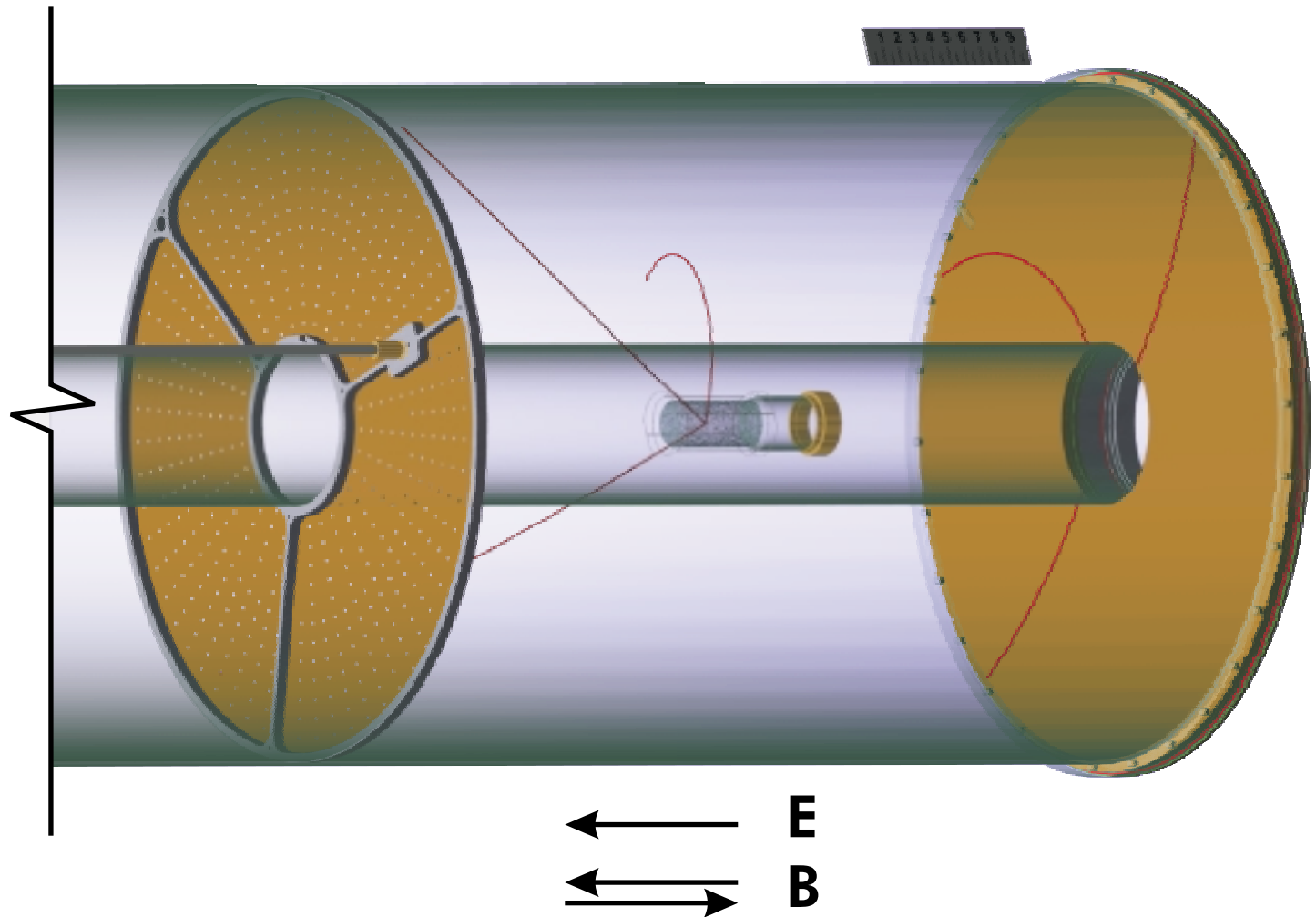
Angular coverage	$20^\circ < \theta < 155^\circ$
Momentum resolution $\sigma_p/p$	$< 6\% \pi, < 12\% p$
Angular resolution $\sigma_\theta$	$< 20 \text{ mrad}$
Dead time/event	$< 400 \mu\text{s}$
Average event size	200 words
Efficiency	$> 95\%$ for $\leq 3$ tracks

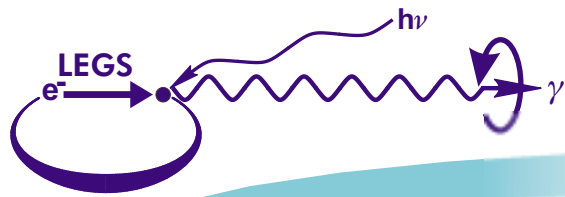


# The LEGS TPC

Track Projection in a TPC

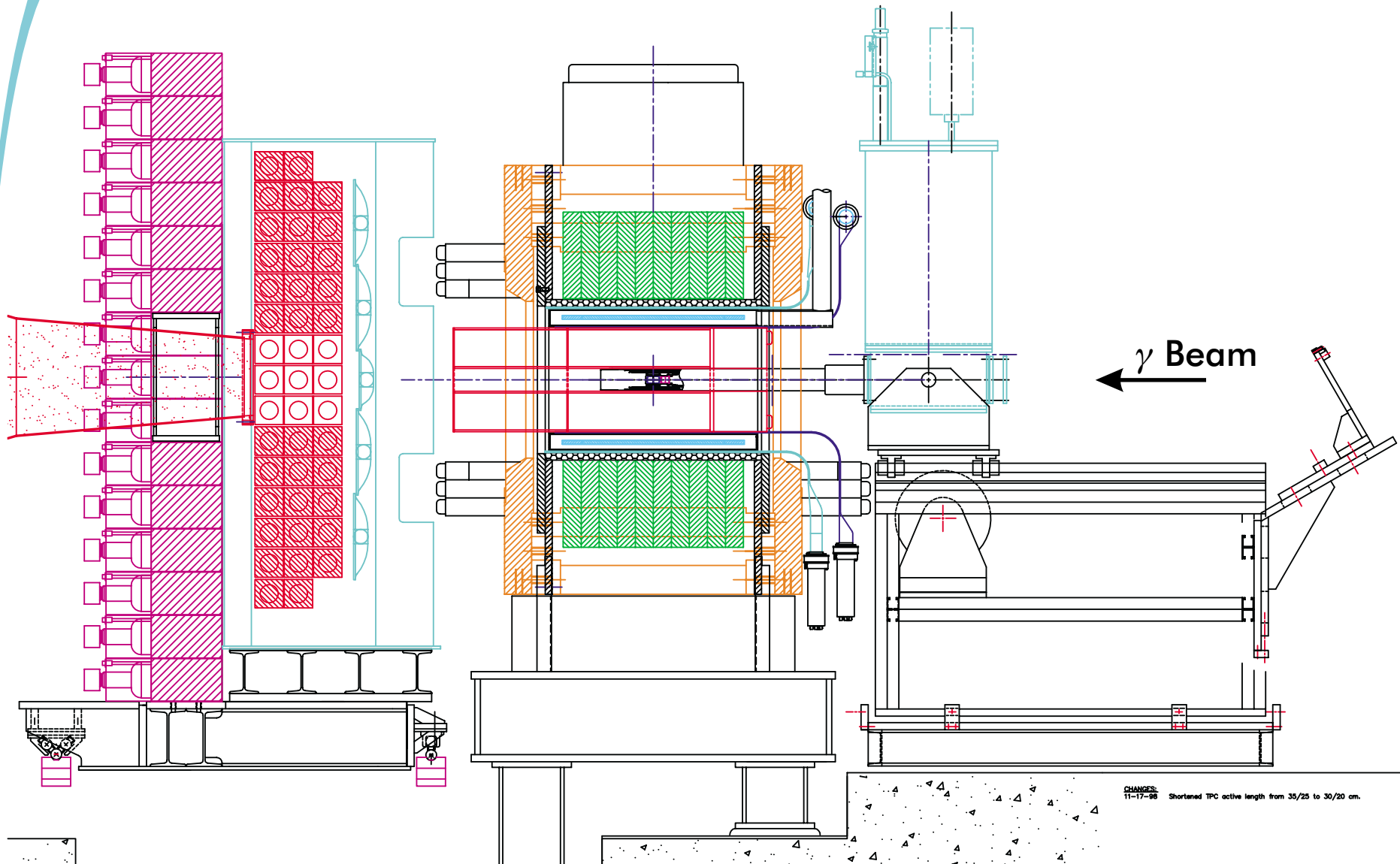
$p \pi^+ \pi^-$

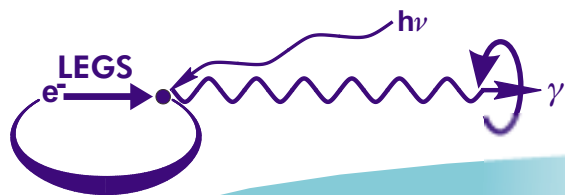




## The LEGS TPC

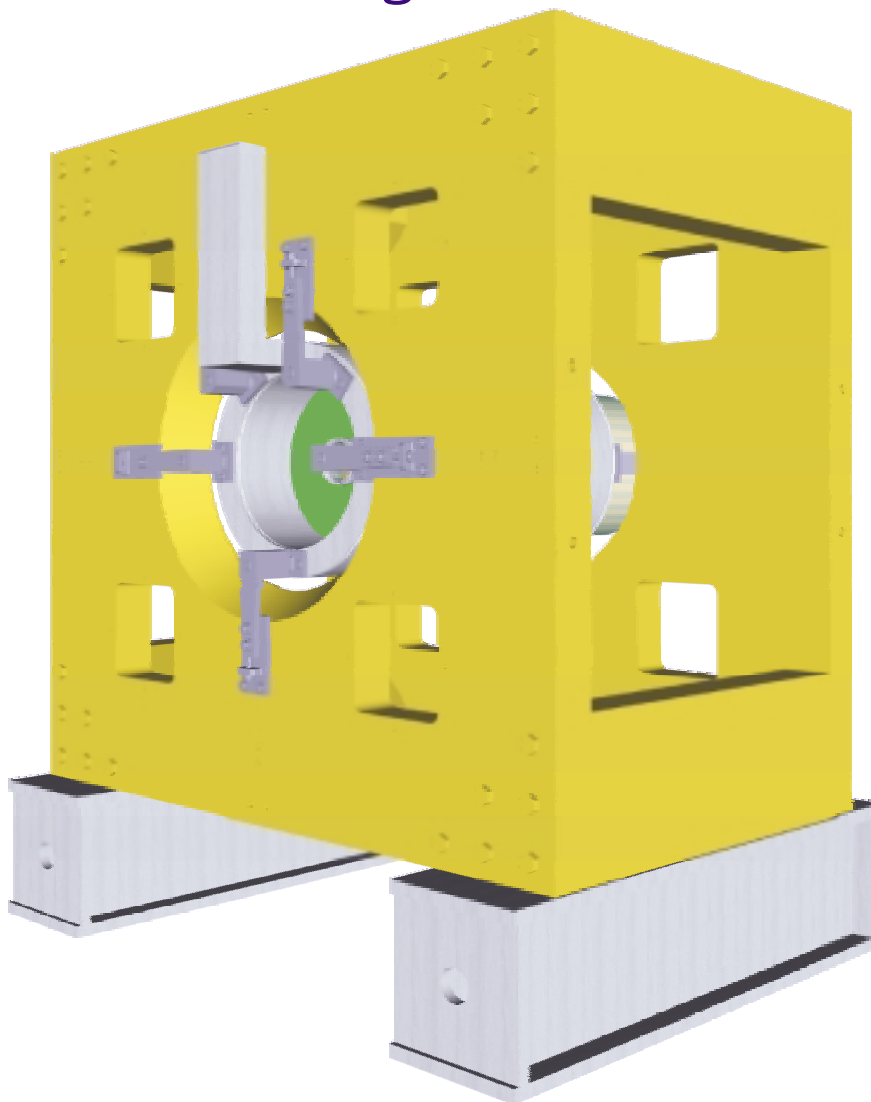
### Cross-section of SASY with LEGS TPC

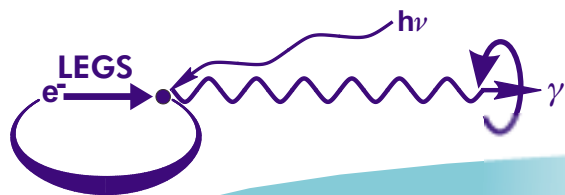




## The LEGS TPC

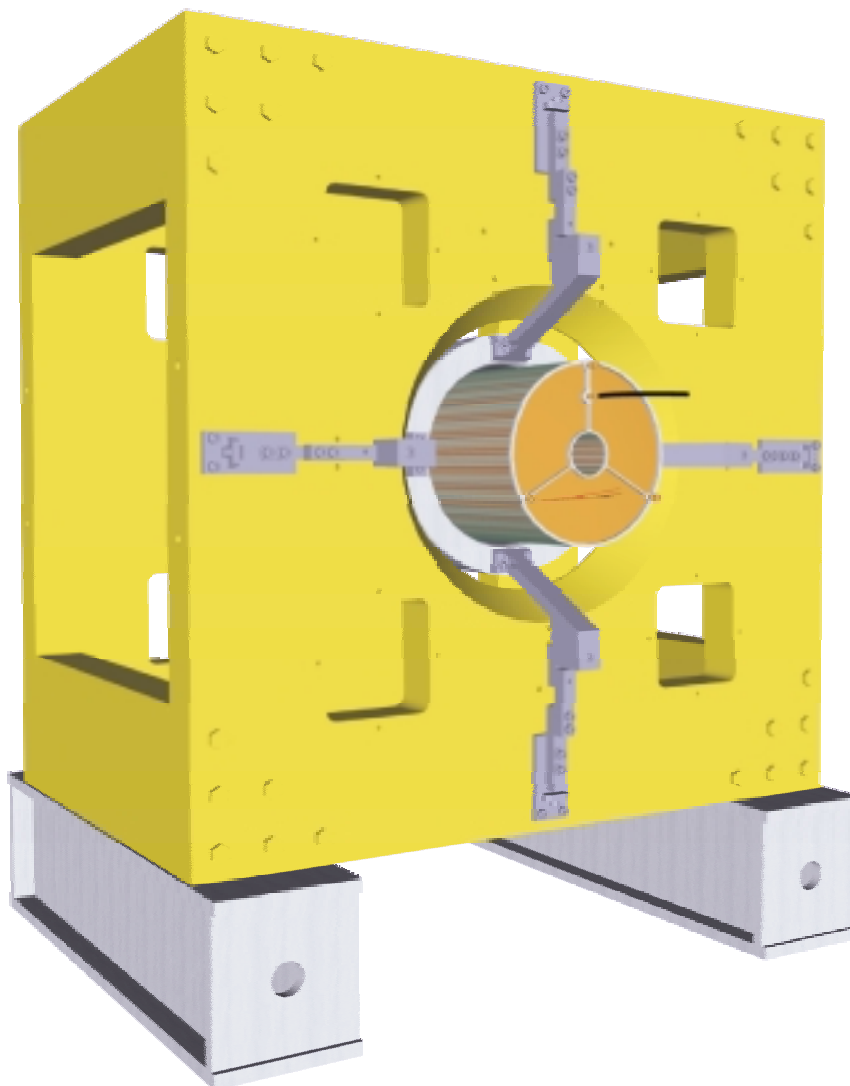
The LEGS TPC mounted in the SC solenoid  
looking downstream



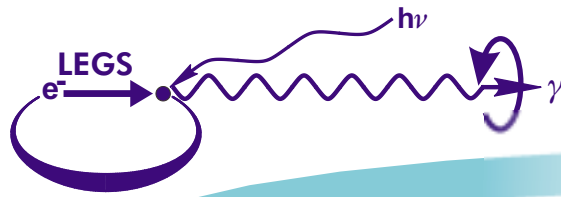


## The LEGS TPC

The LEGS TPC mounted in the SC solenoid  
looking upstream



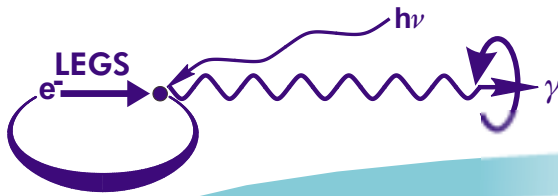




## The LEGS TPC

Beth Magnet - looking downstream





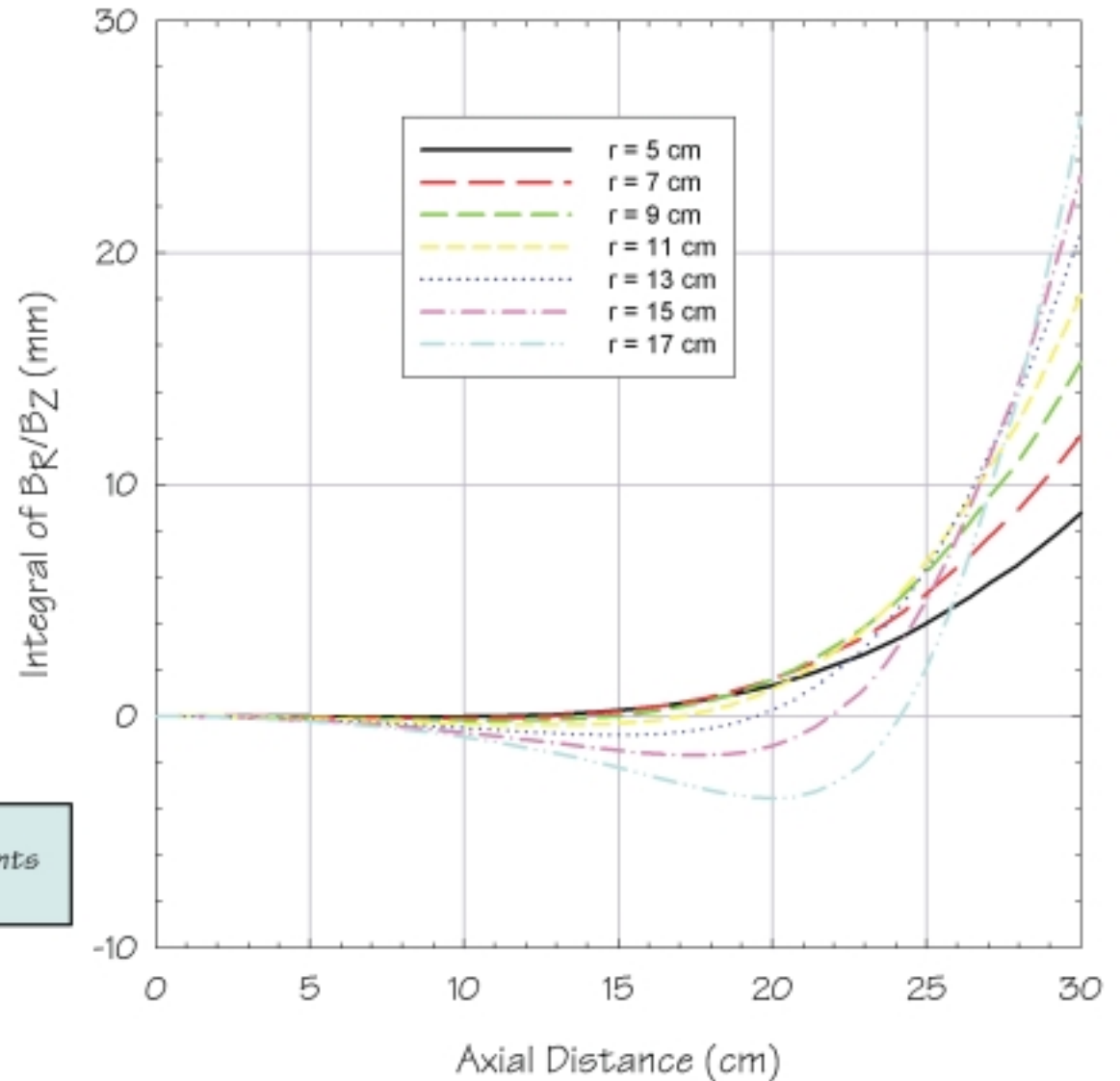
# The LEGS TPC

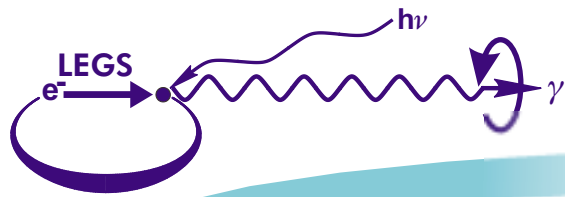
Radial component of magnetic field

Beth Magnet  
 $B_0 = 1.8 \text{ T}$

Track distortions are caused by non-parallelism of E and B in drift region


Divide by  $\omega\tau$  ( $\sim 3$ ) to get track displacements

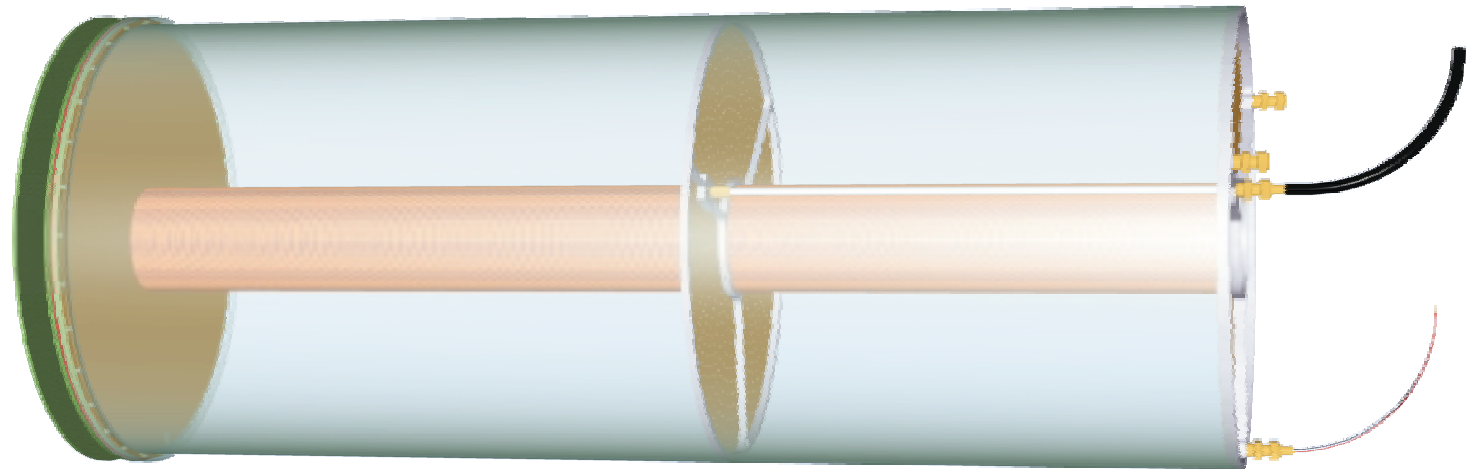
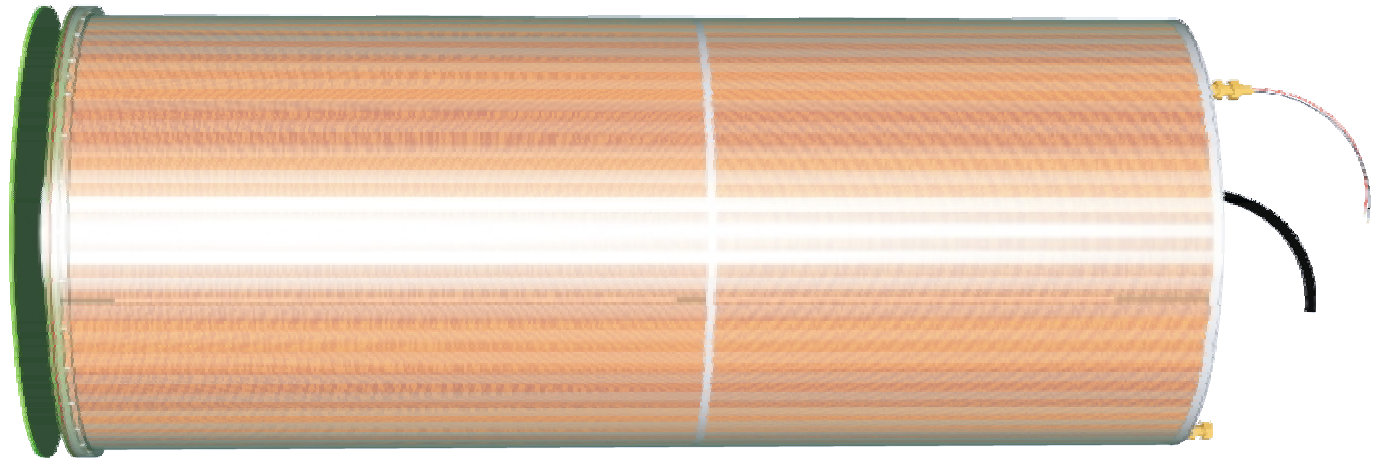


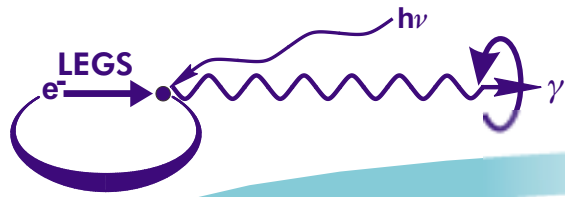


## The LEGS TPC

TPC model with & w/o Gradient Rings

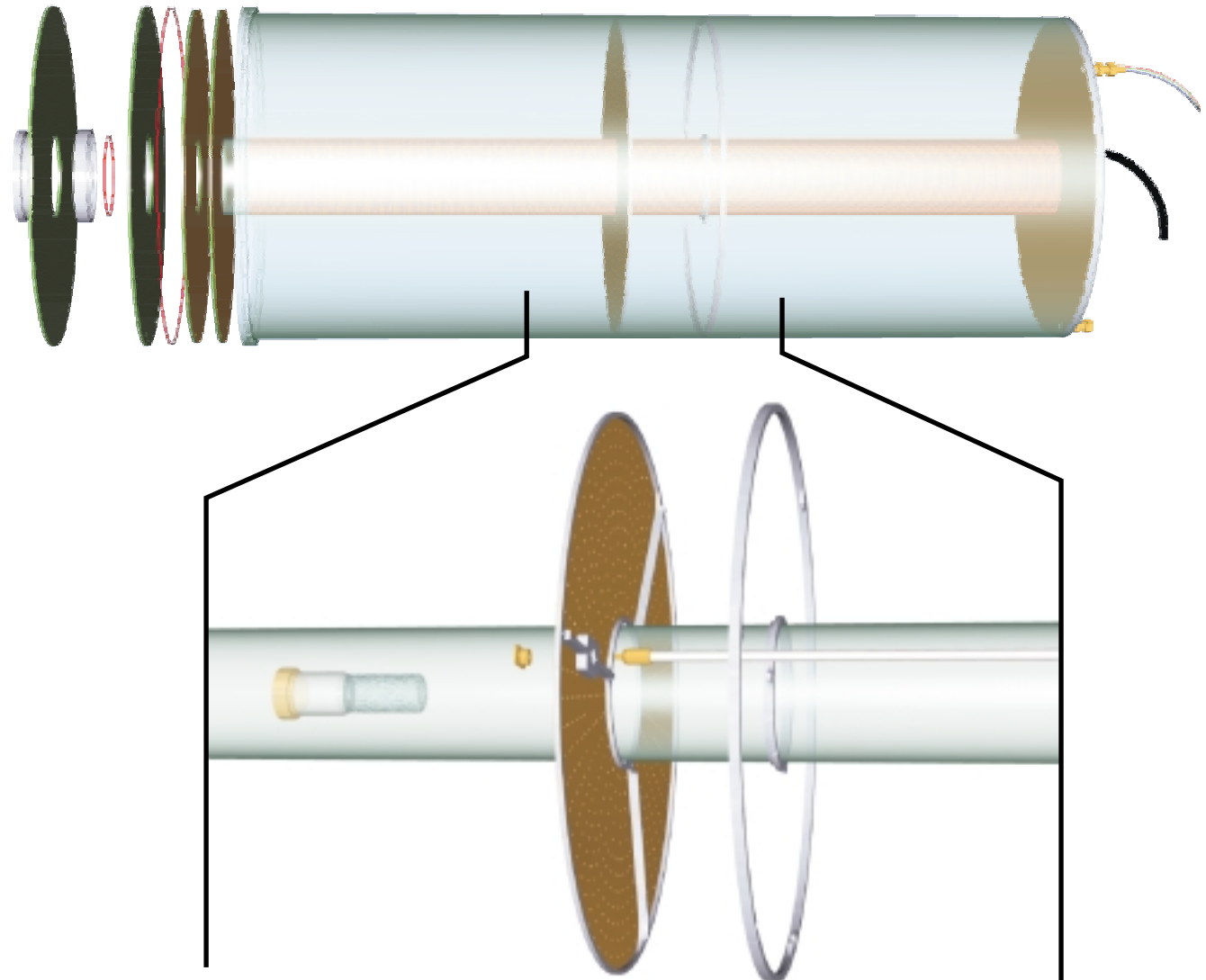
$\gamma$  Beam 

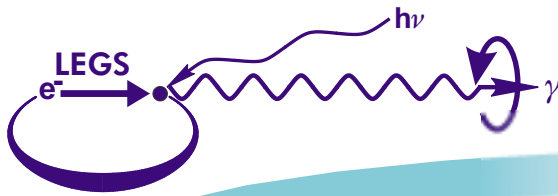




# The LEGS TPC

TPC model - exploded to show assembly

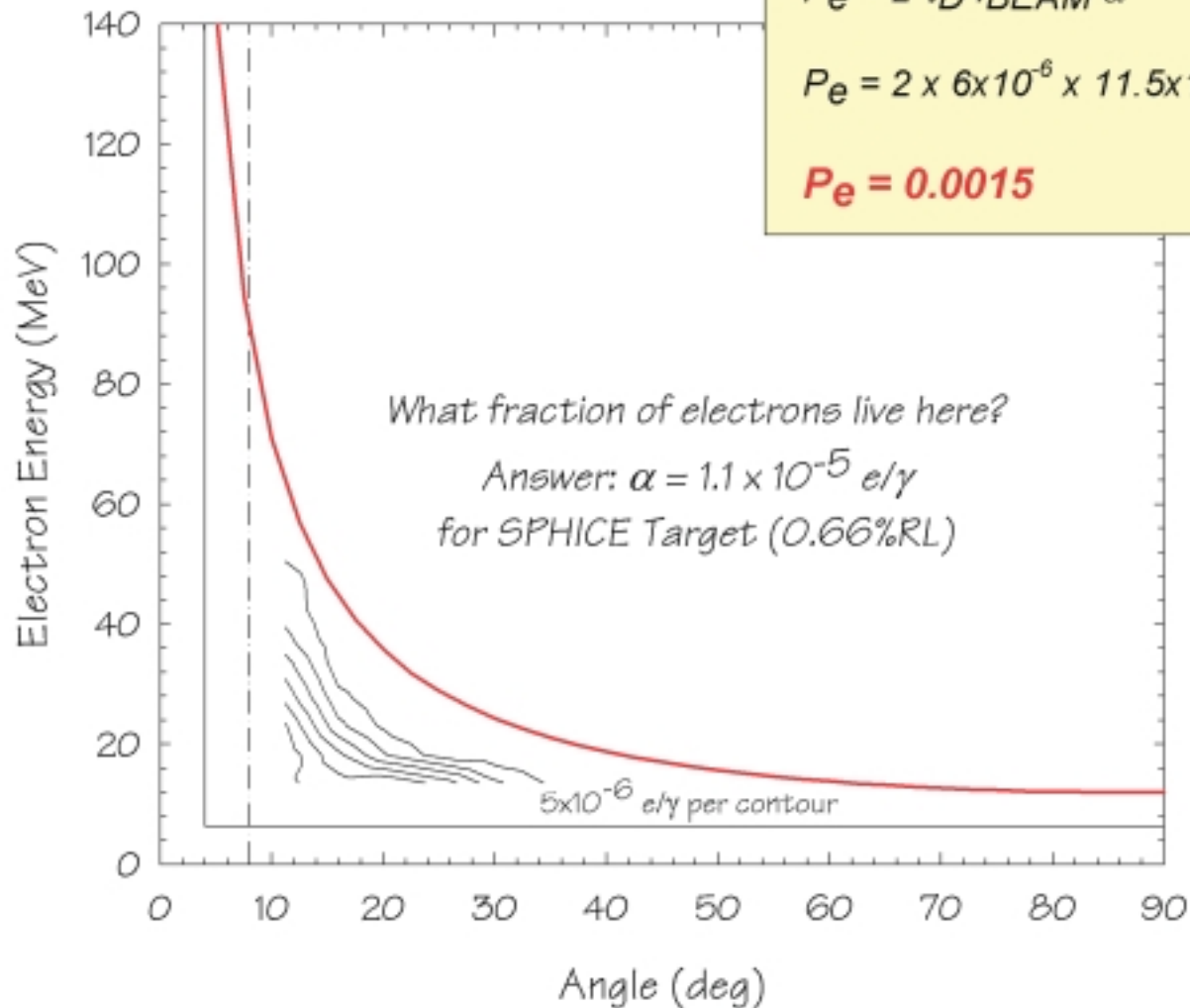




# The LEGS TPC

## Electrons in LEGS TPC

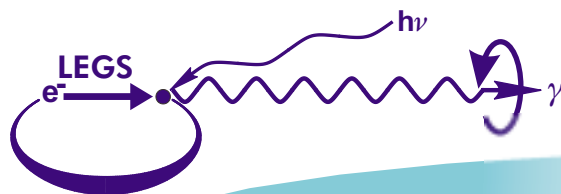
Only electrons to the right of the vertical line and above the solid curve enter the SASY TPC



$$P_e = 2 \tau_D f_{\text{BEAM}} \alpha$$

$$P_e = 2 \times 6 \times 10^{-6} \times 11.5 \times 10^6 \times 1.1 \times 10^{-5}$$

$$P_e = 0.0015$$



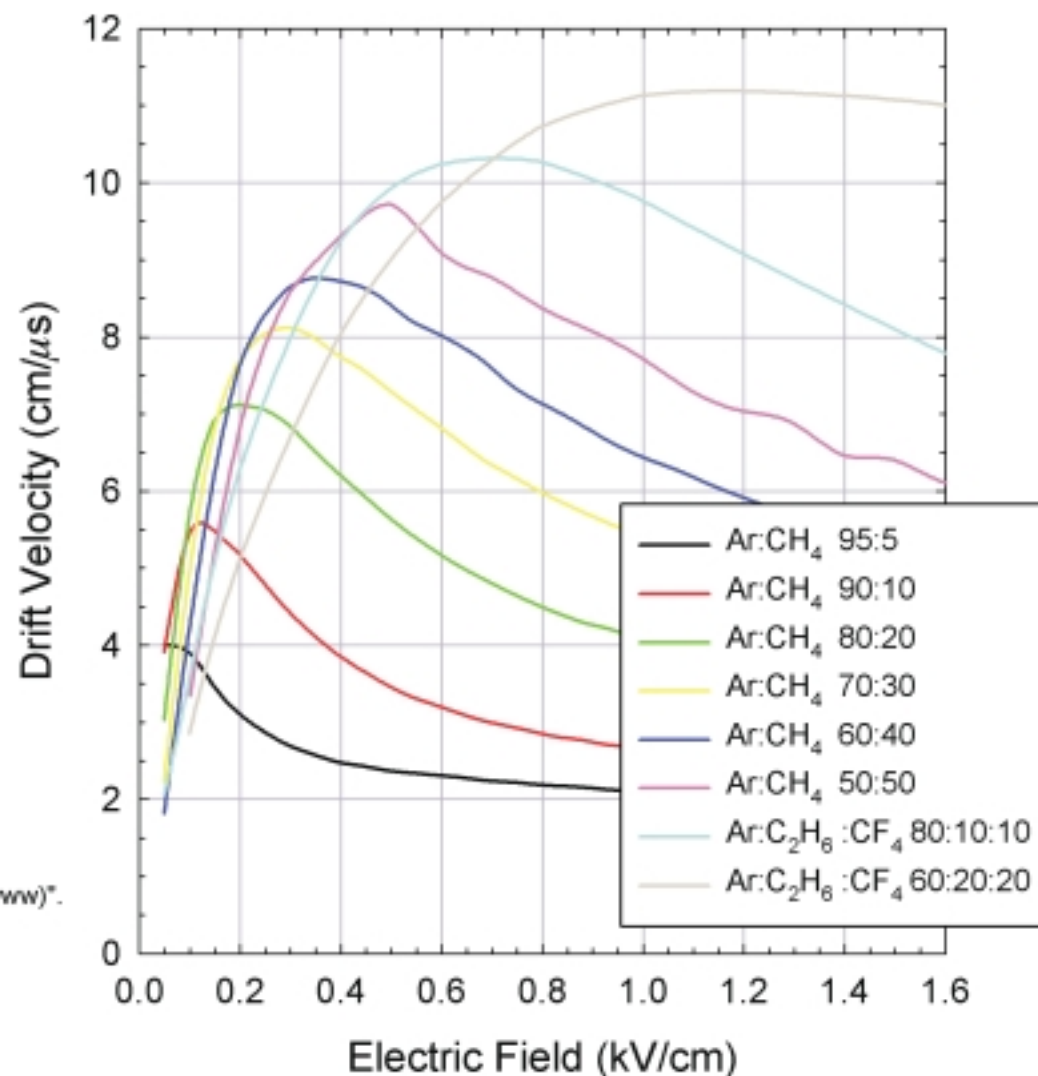
## The LEGS TPC

### Optimizing the Drift Gas

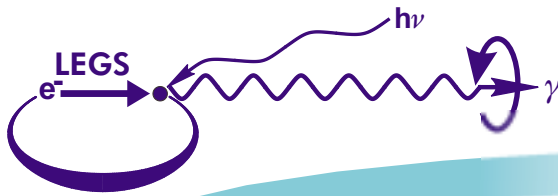
Properties for a 50 cm long drift				
Mixture	HV (kV)	Drift Time (μs)	$V^2 \frac{d^2 z}{dV^2}$ (mm/% <sup>2</sup> )	$dN/dz$ (e <sup>-</sup> /mm)
Ar:CH <sub>4</sub> :: 95:5	3.44	11.77	-1.50	6.12
Ar:CH <sub>4</sub> :: 90:10	6.43	9.10	-1.56	5.93
Ar:CH <sub>4</sub> :: 80:20	10.39	7.02	-0.75	5.55
Ar:CH <sub>4</sub> :: 70:30	14.48	6.16	-1.15	5.18
Ar:CH <sub>4</sub> :: 60:40	17.65	5.71	-1.06	4.80
Ar:CH <sub>4</sub> :: 50:50	24.90	5.14	-3.32	4.42
Ar:C <sub>2</sub> H <sub>6</sub> :CF <sub>4</sub> :: 80:10:10	35.01	4.83	-1.11	6.92
Ar:C <sub>2</sub> H <sub>6</sub> :CF <sub>4</sub> :: 60:20:20	61.25	4.47	-0.44	7.53

Reference:  
U. Becker et al., "Gas R&D Home Page (<http://cyclo.mit.edu/drift/www>)".

Drift Velocity of Gas Mixtures  
for B || E





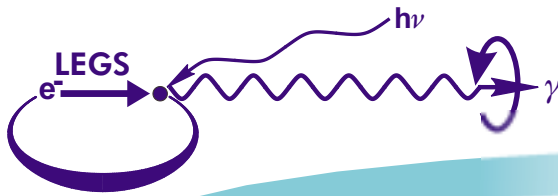


# The LEGS TPC

## Gas mixing and storage system

Gas for 40 days of operation is mixed, stored, circulated, analyzed, and purified. Produces 3 component mixtures

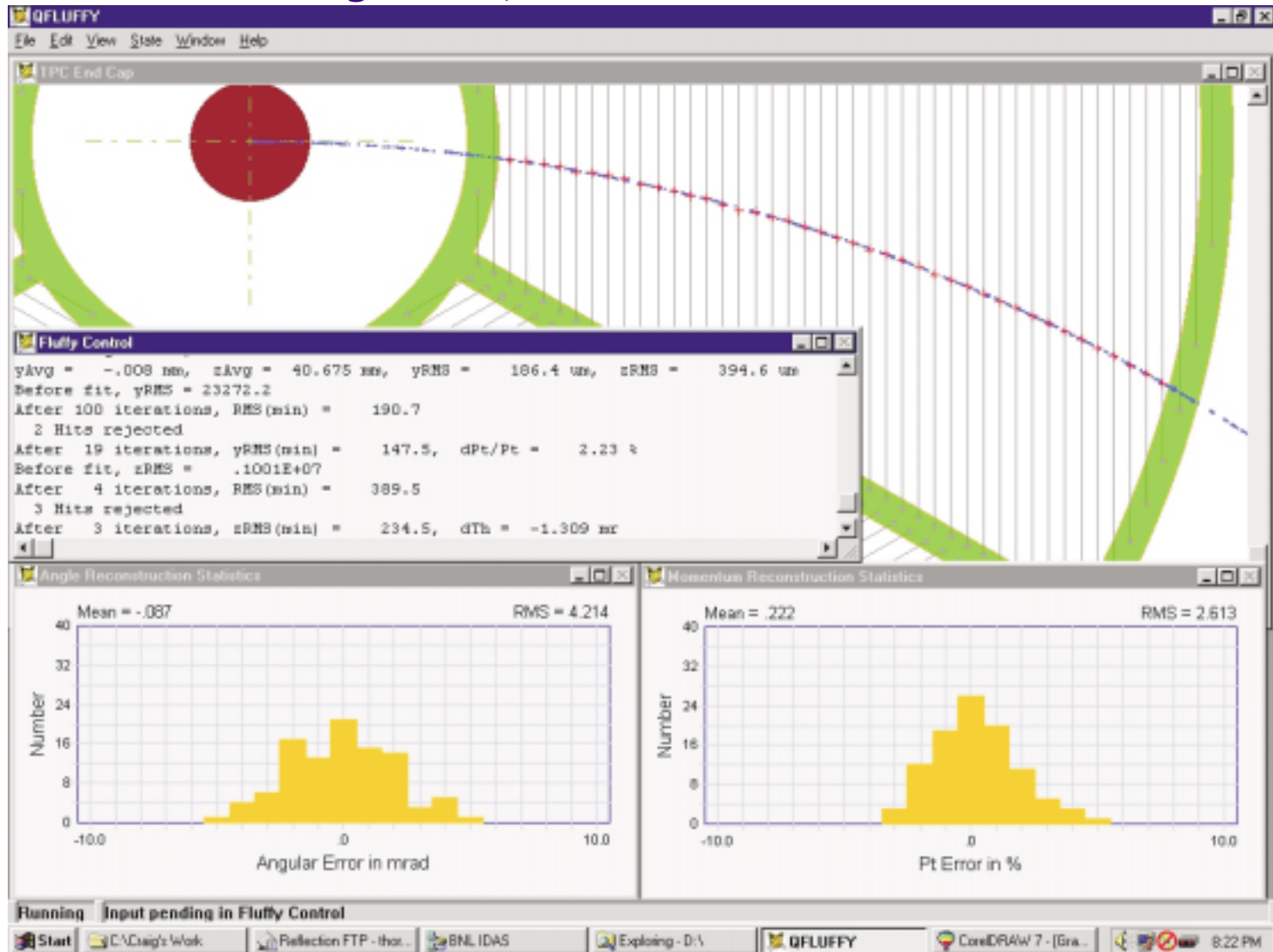




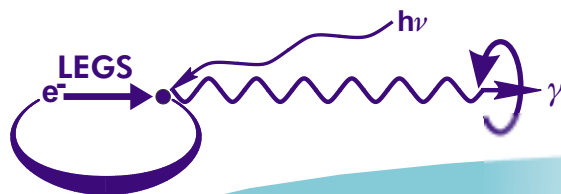
# The LEGS TPC

Fluffy + Garfield - a realistic model

including track formation, drift, charge amplification,  
digitization, and track reconstruction







## The LEGS TPC

Fluffy + Garfield - a realistic model

LEGES TPC

Pions

Fractional Energy Resolution (RMS)

Beth Magnet with  $B_0 = 1.8T$

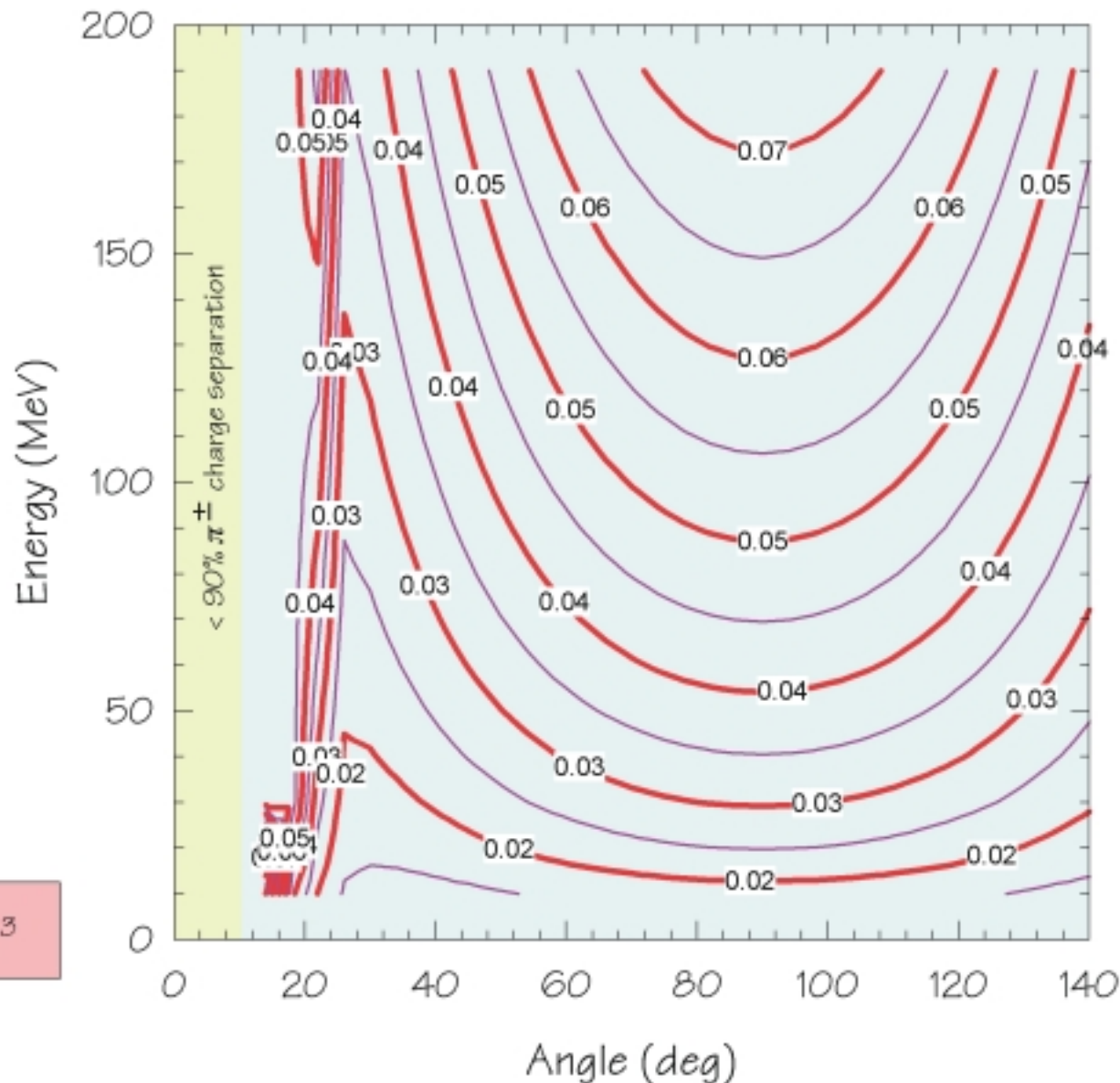
$R_{min} = 48 \text{ mm}$ ,  $R_{max} = 173 \text{ mm}$

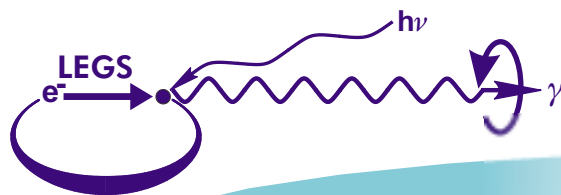
$0.35 \text{ cm} > Z_{TPC} > -0.25 \text{ cm}$

24 pad rows

FLUFFY + GARFIELD:  
GEM w/  $300 \mu\text{m } \Delta x$

99.9% charge separation requires  $\sigma p/P < 0.3$





## The LEGS TPC

Fluffy + Garfield - a realistic model

LEGS TPC  
Protons

Fractional Energy Resolution (RMS)

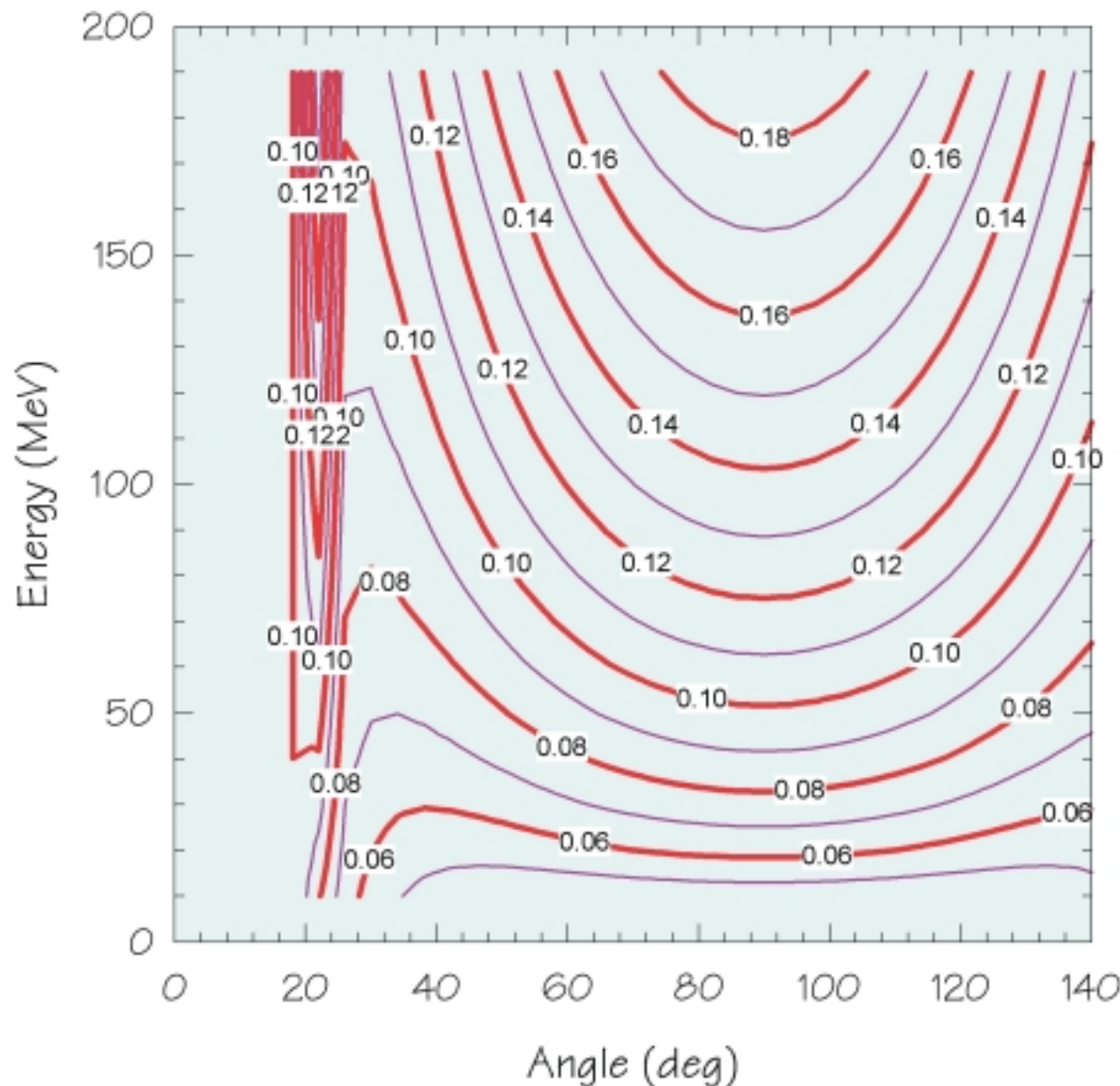
Beth Magnet with  $B_0 = 1.8T$

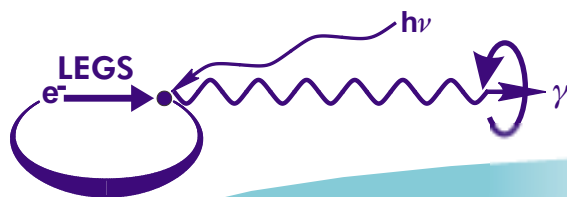
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$0.35 \text{ cm} > Z_{TPC} > -0.25 \text{ cm}$

24 pad rows

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GEM w/  $300 \mu\text{m } \Delta x$





# The LEGS TPC

Fluffy + Garfield - a realistic model

LEGS TPC

Pions

Fractional Energy Resolution (RMS)

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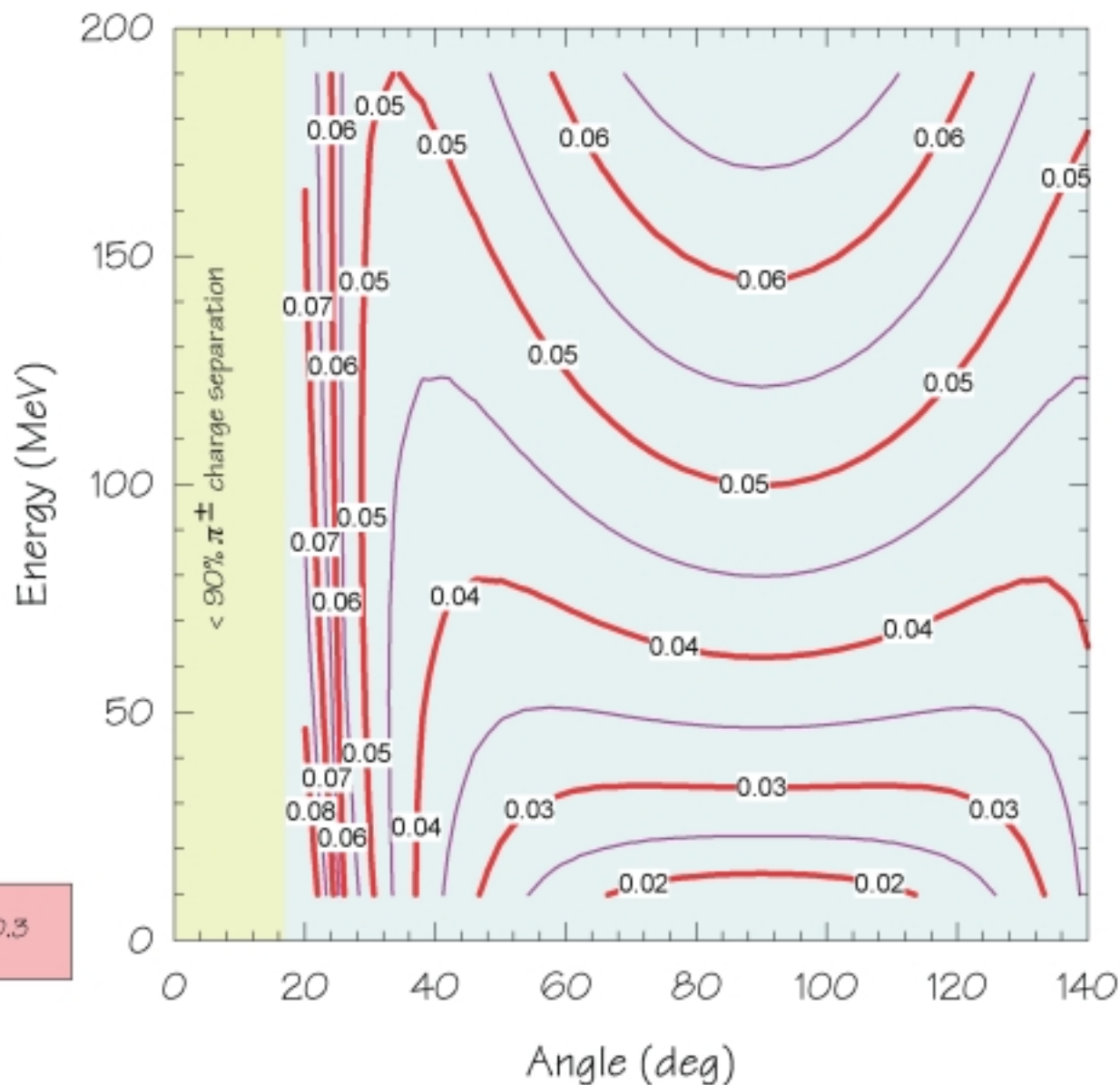
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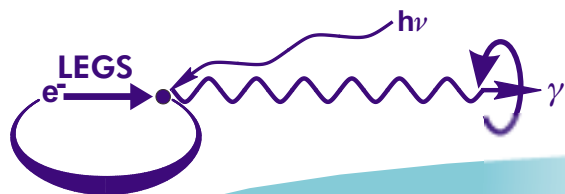
$0.35 \text{ cm} > Z_{TPC} > -0.25 \text{ cm}$

28 pad rows

FLUFFY + GARFIELD:  
Wires in 6 segments

99.9% charge separation requires  $dP/P < 0.3$





## The LEGS TPC

Fluffy + Garfield - a realistic model

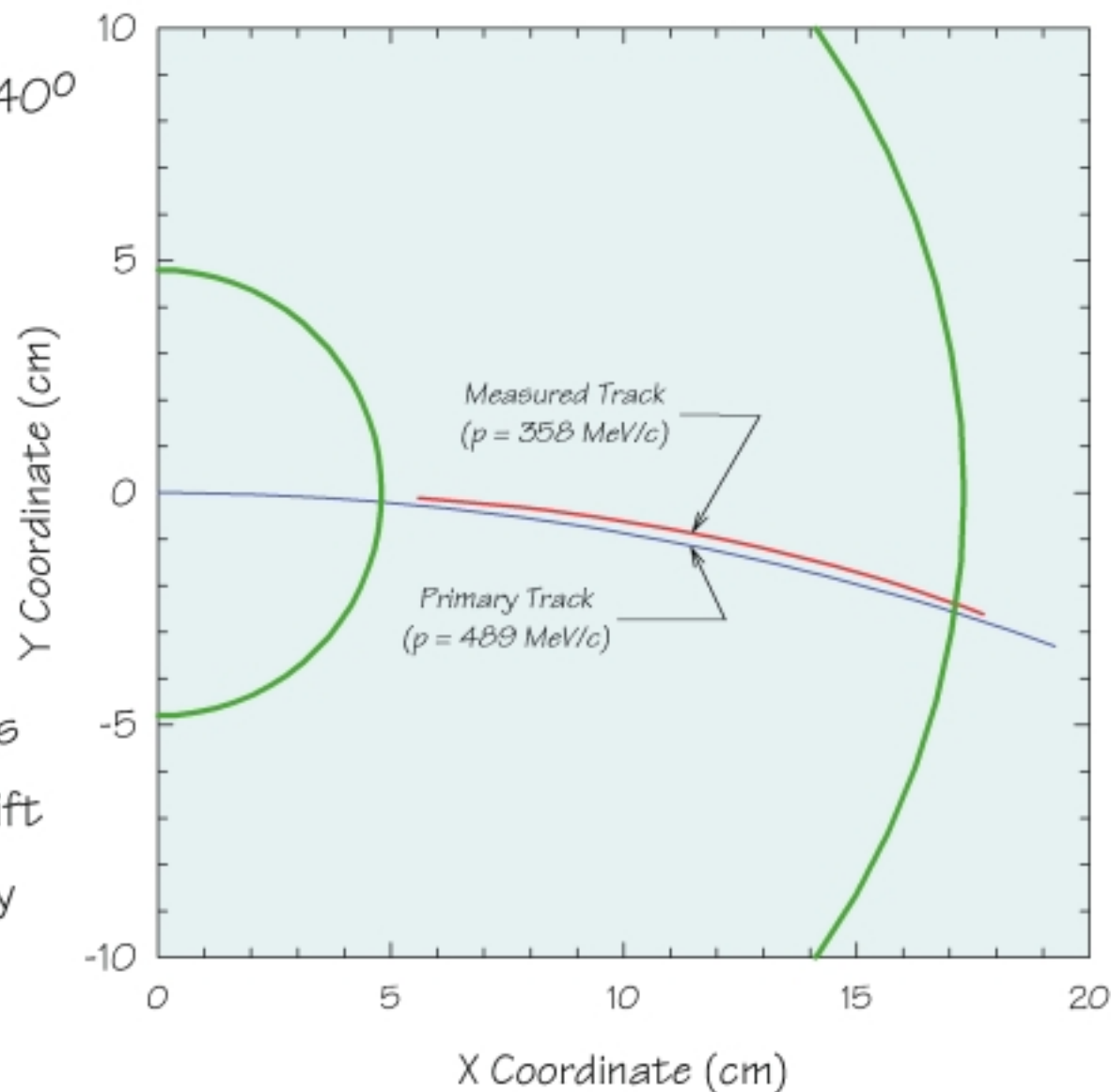
120 MeV Protons at  $40^\circ$

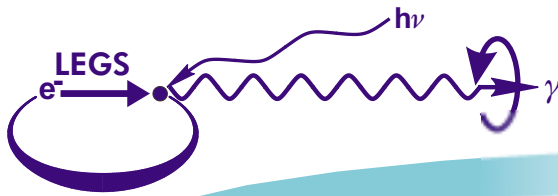
$$\omega\tau = 3.6$$

Beth Magnet

$$B_0 = 0.3 \text{ T}$$

$B_r$  component adds  
 $v_\phi$  component to drift  
that varies radially





# The LEGS TPC

## TPC Design

Status  
May 12, 2005

1. **Short (10 cm) TPC prototype is successful**  
*tracks!*
2. **Major parts of TPC are in hand at BNL**  
*minor parts are in production*
3. **ASICs are complete and successfully tested**  
*full (production) quantity was delivered in Fall '04*
4. **Anode pad board layout is complete**  
*an octant of the full board produces tracks;  
the revised full board is ready for fabrication*
5. **DAQ hardware is nearly complete**  
*prototype version is being used for tests*
6. **Gas system is complete and in use**
7. **SC Solenoid & yoke were assembled & operated**  
*cryostat is being modified to reduce liquid He usage*